MICRO COMMUNICATIONS, INC.

87-268

COMMENTS

ON

REPORT AND ORDER

MM DOCKET #87~~-268~~

ORIGINAL FILE

REPORT NO. 1676

JULY 15, 1992
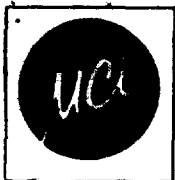
Micro

communications inc.

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JUL 16 1992

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

July 15, 1992

Federal Communication Commission
1919 M Street, NY
Washington, DC 20554

87-268 / RECEIVED

JUL 16 1992

Attn: Office of the Secretary
      Donna R. Searcy

FCC MAIL BRANCH

Subject: Comments on Report and Order for proposed
         Rule Making MM Docket #~~87-263~~.

Dear Sirs,

    The Commission should be aware that there are new TV transmitting antenna's now
available that could have a significant impact on Policy making matters. The new antenna is
called the *"All Band Antenna"*. [1]

    MCI has been supplying the *"All Band Antenna"* to the International Market for a number
of years and more recently to the American market [2], where as many as 5 channels can be
combined and radiated with identical performance from the one master antenna.

* AREA ASSIGNMENT

    Because the MCI antenna can handle any channel [e.g. CH. 14-69 (UHF) or
    CH. 7-13 (VHF)] the Commission does not have to assign closely spaced channels to a
    given market.

    This will permit assignments to be based on technical matters such as interference and
    not on political, financial, or convenience.

* NTSC/ATV

    The MCI antenna can handle the *NTSC* and *ATV* signal at the same time (assuming these
    are in the same band). Antennas now purchased for a *NTSC* signal can be used with the
    ATV signal regardless of the channel assigned.

* RANKING & SWAPPING

Ranking of stations in a market, swapping or reassignment by the Commission will not make obsolete antennas already purchased.

* SAME TOWER

The MCI antenna is a *wrap around antenna* [3] that will not interfere with the top mounted *NTSC* antenna. This will permit the existing tower and transmitter building to be used.

The station coordinates will not chance for most facilities.

* COSTS

The cost for the new line and antenna can be shared by the number of stations on the *"All Band Antenna"*. Typical costs are included. [4]

* IDENTICALNESS

Because each radiating element is a basic module and covers the full band, all antennas regardless of gain or pattern shape have identical radiating elements, only the harness (coax cable) has to be changed to accommodate the different transmit powers.

These radiating elements are now being manufactured for the International Market , in quantities of *3,000* to *5,000* per year. There should be no problem in meeting the industries requirements.

Yours truly,

Tom Vaughan

Thomas J. Vaughan
President

TJV/dmb

enclosures: (1) Multichannel TV Antennas
(2) Rural Services Turns To MCI
(3) Antenna & Transmission Line For The Simulcast Period
(4) Location & Costs of HDTV - Antenna System

Multichannel TV antennas

Broadband radiators make sense for today and tomorrow.

By Dennis M. Heymans

The Bottom Line

Antennas that are tuned to a single channel have long been the norm, but today's fiscal realities are causing some broadcasters to explore alternatives. Improved cost effectiveness at the transmitter site is possible when an antenna is shared by two or more stations. Signal quality and/or coverage may also be improved. Multichannel systems could play an even larger role in the HDTV transition by allowing use of the same antenna for NTSC and HD simulcast channels. $

Heymans is sales manager for Micro Communications, Manchester, NH.

Multichannel antenna systems have been used in FM radio and by international broadcasters in general for many years. But relatively few American TV broadcasters have realized the benefits of these systems until recently. In today's marketplace, it makes good economic sense to co-locate, thereby minimizing initial capital expenditures. This approach can help each station involved in a shared system in several ways:

- Lower start-up costs for tower and transmission line.
- Sharing of the prized "tower top."
- Reduced physical construction at the site (buildings).
- More space available on the tower.
- Reduced intermodulation and ghosting.
- Reduced RF radiation problems at the site.

Because of the ever-increasing pressures and local restrictions on antenna installations, it is important to have a system that is expandable and in compliance with local ordinances. Non-ionizing radiation issues have also become important for site approval. Community antennas for new or existing structures that minimize downward radiation will reduce these approval hurdles.

Antenna element characteristics

The first items to be examined are the radiating elements. A wideband antenna often uses a modular panel design, which can provide various azimuth and elevation patterns.
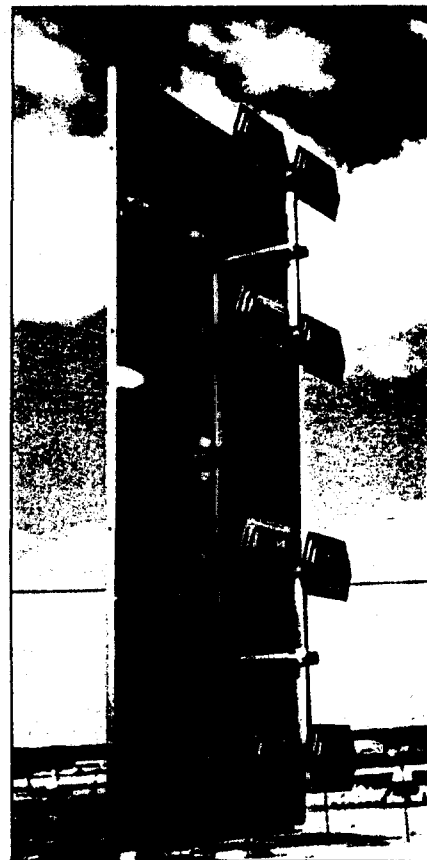
Figure 1 shows five standard azimuth patterns. Special patterns can be easily configured using panel elements. Shaping of the pattern with null-fill also provides excellent near-field coverage. A wide range of total system gains is also available, running anywhere from four to more than 130 times the input power.

The VSWR performance of an individual panel is typically 1.10:1 over the entire UHF band (470MHz-800MHz). Construction of the panel consists of a number of dipoles mounted in front of a reflector. Research has shown that a flat dipole is far superior in performance to a tubular dipole.

Dividers, cables and feed systems

The only way to ensure a broadband system is to start with wideband basic components. Panels, power dividers, flex and rigid coax lines are the required building blocks. The antenna panels used in these systems are designed to exhibit wideband response, as previously mentioned. Power dividers are simply multistepped impedance transformers and are broadband devices. Coax cables or rigid

A single panel from a multichannel panel array, with radome removed.

OMNI

WIDE CARDIOID

PEANUT

NARROW CARDIOID

VERY NARROW CARDIOID
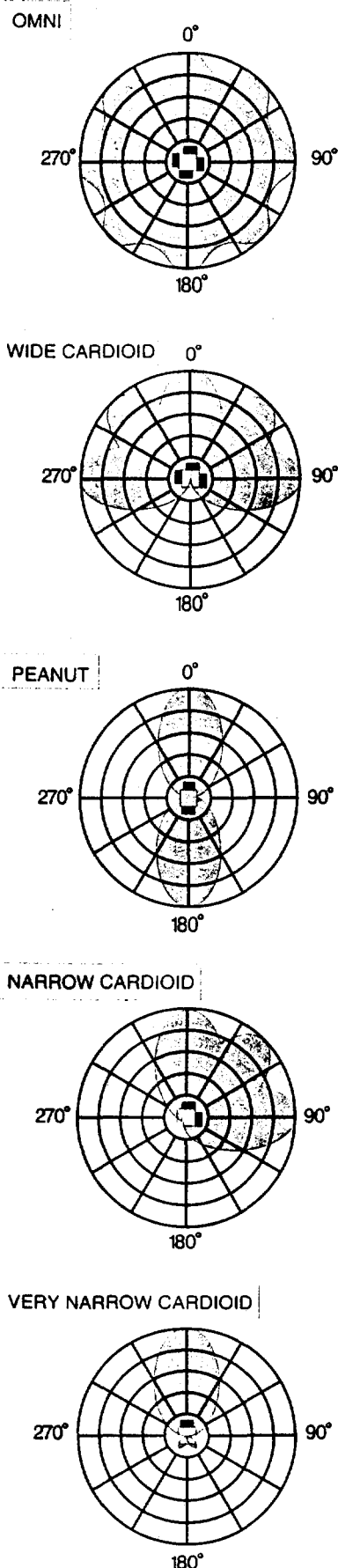
Figure 1. *Polar plots of five standard antenna azimuth patterns.*

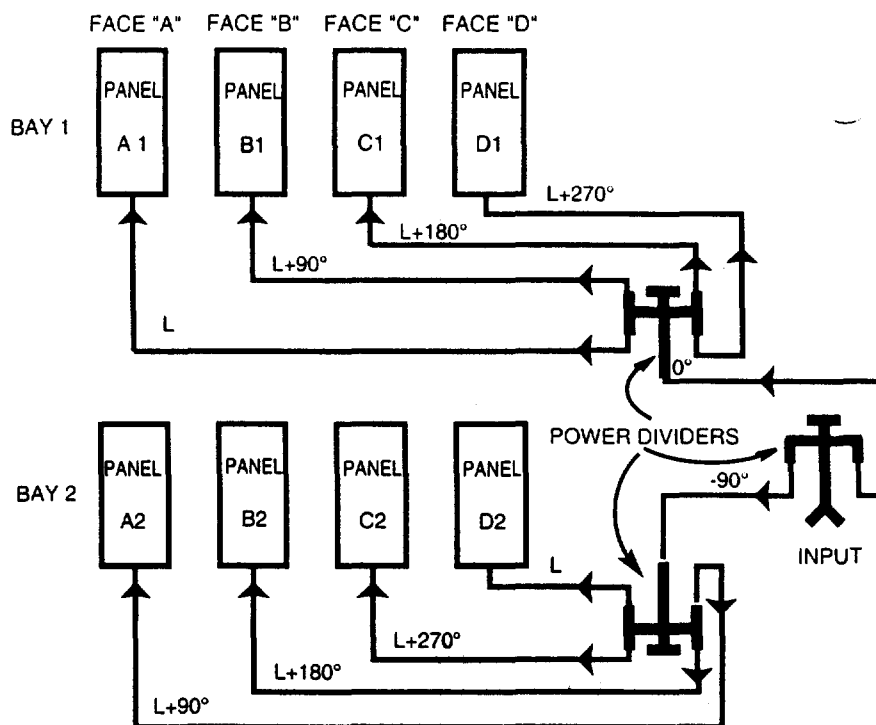FACE "A"   FACE "B"   FACE "C"   FACE "D"

Figure 2. *Quadrature phasing of a 2-bay panel antenna.*

lines are inherently wideband. All that remains is the assembly of these items into a system that retains the individual wideband nature of each of its components. This is the role of the feed harness.

By using a branch (or parallel) feed system, it is possible to have a complete antenna system with good performance over the entire band. The branch feed system allows the use of *quadrature phasing* to perform the required impedance compensations.

Quadrature phasing provides complete cancellation of identical signal reflections through the use of quarter-wave difference cables. Feeding a power-divided RF signal to radiating elements via this so-called cable phasing arrangement allows the required bandwidth to be achieved. Figure 2 illustrates the use of quadrature-phased cables in a 2-bay array.

This principle is based on the physics of phase rotation. If all the radiating elements present an identical load to the transmitter in terms of amplitude and phase, the result will be complete cancellation of reflected power. To accomplish such complete cancellation with four identical dipole panels, they must each be fed with vectors of the same amplitude but quadrature-phased. As Figure 2 shows, the signals feeding the four panels of each bay are phased 0°, 90°, 180° and 270°, respectively. This causes any reflected RF coming back from the panels to cancel at the power divider.

Other methods of reflected-power cancellation using RF hybrids can also be used. These involve mechanical polarity inversion of the panels (i.e., exchanging panels top to bottom), and the use of quadrature phasing with 3dB hybrid couplers.

Panel displacement

Complementing the phasing of the feed cables is the mechanical displacement of the panels around the tower. In displacing each panel by a certain physical offset, the correct phase of the combined radiated field is achieved.

The only way to ensure a broadband system is to start with wideband basic components.

This allows tight control of coverage patterns, and provides the possibility for easily adjustable, constructive interaction between antenna elements. The actual amount of offset is calculated from the geometry of the panel layout.

Channel combiner technique

Equally important in a wideband feed antenna system is the method in which multiple RF channels are fed to it. Two approaches are used today to combine the outputs of multiple transmitters into a common RF signal: *constant impedance*
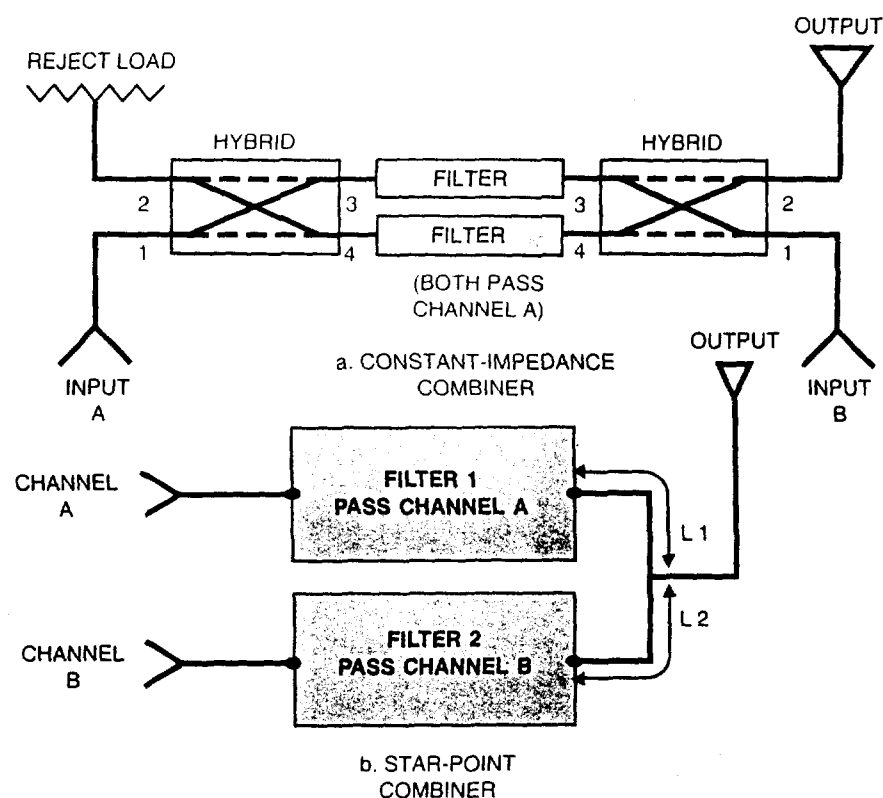
REJECT LOAD

HYBRID

2　　　3

FILTER

FILTER

1　　　4

HYBRID

3　　　2

4　　　1

(BOTH PASS
CHANNEL A)

OUTPUT

INPUT
A

INPUT
B

a. CONSTANT-IMPEDANCE
COMBINER

CHANNEL
A

FILTER 1
PASS CHANNEL A

L 1

OUTPUT

CHANNEL
B

FILTER 2
PASS CHANNEL B

L 2

b. STAR-POINT
COMBINER

Figure 3. *Two methods of combining transmitters to feed a common wideband antenna.*

and *star-point* combiners.

Constant-impedance types use two identical filters placed between quadrature RF hybrids, while star-point systems feed each signal through a single filter, then combine all filter outputs at a common tee junction. (See Figure 3.)

Constant-impedance combiners

The constant-impedance combiner uses the quadrature phasing relationship of the 3dB hybrid alluded to earlier. As Figure 4 indicates, when a signal is introduced to port 1 of such a hybrid, it is split equally (in terms of power) to ports 3 and 4. Port 2 is isolated from port 1, and therefore sees no power. Now if outputs 3 and 4 are each short circuited, all the power will reflect and appear at port 2 because of the phase relationships in the hybrid.

The constant-impedance channel combiner (Figure 3a) combines two RF signals (channels A and B) as follows: Channel A is split in the first hybrid and passed through two identical bandpass filters tuned to that channel. The split/quadrature signal arrives at the second hybrid and is combined, because of the signals' phase relationship, at the output (port 2 of the second hybrid). If the filters are identical in performance, channel A's output will not appear at channel B's input (port 1 of the second hybrid). This isolation between channels also depends on the performance of the two hybrids in the circuit.

Meanwhile, channel B is split in the second hybrid, and the two outputs each see an effective short circuit, because they are

terminated by a filter tuned to another frequency (channel A). These split/quadrature signals then reflect and are combined in-phase at the output (port 2 of the second hybrid). Any small amount of channel B's power that gets through the filters is combined in hybrid No. 1 at its port 2, and absorbed by the reject load terminating this port. Thus, a combination of filtering and hybrid action provides isolation between transmitter outputs, while combining both channels to a single output. This output is then fed via a common transmission line to a single wideband antenna.

Star-point combiners

The star-point combiner (Figure 3b) consists of individual channel filters (each

tuned to the frequency of that channel's input), connected to a common tee. The bandpass characteristics of each filter allow that channel to pass, while rejecting all the other channels. If the rejection of the filter is high, it will appear as a short circuit to the other channels' transmitters.

Proper combining of channels requires correct design of the transmission lines between the filters and the output tee. At the reject channel, a perfect open circuit must appear at the tee. When L1 and L2 are the

An all-band antenna can handle a station's present needs and its future channel assignment for ATV simulcasting.

correct length, both channels combine at the output with the loss and VSWR of their respective filters.

No additional VSWR or loss is added from the other channels' operation. Isolation between inputs is purely a function of filter rolloff. Therefore, the star-point combiner's performance relies solely on the performance of its filters.

Multichannel installation

Each of the combiner designs that has been described has its strengths and weaknesses. For instance, to combine more than two channels, constant-impedance combiners must be linked together in series, while star-point combiners can accommodate many channels in a single assembly. Although this would seem to be an advantage for the star-point design, most multichannel installations have traditionally chosen the constant-impedance approach because it allows easy incremental expansion in the future. Table 1 (below) summarizes the advantages and disadvantages to both combiner types.

CONSTANT IMPEDANCE		STAR-POINT	
Pro	Con	Pro	Con
Expandable	Hybrids have effect on performance	Less costly	Not expandable
Each channel has separate modules	Many connections	Filter determines performance	All isolation comes from filters
Lower power modules are used at input	Losses add up as modules are added	All inputs similar in performance	Frequency-selective only
Various power levels can be used	Powers to be used must be predetermined	Smaller size	Not expandable
		Constant power inputs	Tee junction is power limited

PORT	RELATIONSHIP		
	IN-PHASE	QUADRATURE	NO CONN.
1	4	3	2
2	3	4	1
3	2	1	4
4	1	2	3

PORTS   PORTS

ISOLATED ② → ③ OUT, 90°
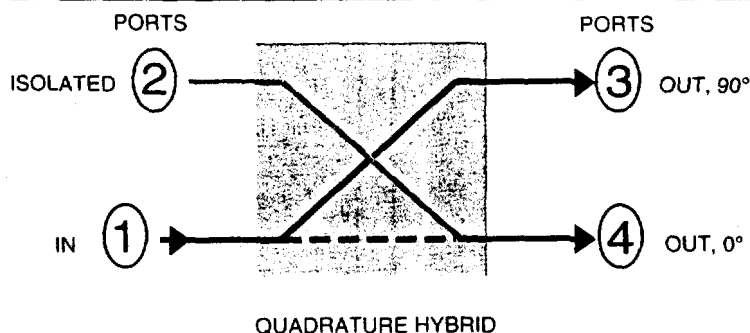
IN ① → ④ OUT, 0°

QUADRATURE HYBRID

Figure 4. The quadrature hybrid and a matrix of its ports' relationships to one another. In the application shown, power coming into hybrid at port 1 exits hybrid through ports 3 and 4 with phase relationships as noted.

HDTV applications
The systems just described are capable of covering the full VHF or UHF broadcast TV bands. In this respect, they may have significant application in the upcoming transition to HDTV broadcasting.

Broadband antennas can provide the following advantages during this transition:

• An all-band antenna means the system is capable of handling a station's present needs and its future channel assignment for any advanced TV (ATV) simulcasting.

• During the simulcast period, NTSC and ATV signals will be transmitted with the same coverage.

• A single transmission line can be used for NTSC and ATV signals.

• Broadband panel antenna systems with non-dispersive transmission lines will provide a linear phase shift across the band and reduce group delay contribution.

• These antennas typically use half-wavelength element spacing, thereby greatly reducing downward radiation.

• Panel-type radiators can be mounted on the faces of existing towers. Their wraparound installation can provide less pattern-ripple than a side-mounted pylon antenna.

• Quadrature phasing provides a system that is insensitive to impedance changes due to antenna icing.

All of these advantages are available today, using current multichannel antenna technology. These systems' immediate benefits in shared transmission facilities are enhanced by their potential future utility in ATV applications. Such an analysis presents some compelling reasons to consider multichannel designs at your facility.

➡ *For more information on multichannel TV antennas, circle Reader Service Number 301.* ∎

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Rural Services Turns to MCI

by George H. Werl Jr., President
Com   ng Inc.

ST. PAUL, Minn. In the rural areas surrounding Pelican Rapids, Minn., low population density and the distances between potential subscribers limited the feasibility of constructing an economically viable cable television system.

Seeking to provide television service to the rural population, Rural Services of Central Minnesota Inc. (RSCMI) looked for alternatives. Among the choices considered were MMDS and

**The top section of the Micro Communications
All-Band antenna is readied for installation.**

LPTV.

Clarence Peterson, president of RSCMI, felt that the hilly local terrain made the decision for him. He applied to the FCC for five non-directional LPTV stations: channels 31, 39, 41, 43 and 51.

The proposed transmitter site was about seven miles southeast of Pelican Rapids, at one of the highest elevations in the area.

Consulting and TDM Broadcast Services were retained by Rural Services to design the facility, supply the equipment and coordinate the on-site construction.

A conventional transmitter providing UHF channels 31 through 51 would employ multiple antennas and perhaps diplex or triplex the more closely spaced channels. There are, of course, potential problems with this approach, especially considering the interaction between the antennas and the tower structure itself.

Broadcast solution

Fortunately, at the time of the RSCMI installation, we were working on another project—an eight-station FM site using a bandpass-type combiner and a common panel antenna. Based on our experience with the multi-station FM installation, we decided to investigate a similar   nna as a possibility for Rural Servic

Use of a panel antenna for the UHF LPTV facility would eliminate the problem of pattern irregularities due to tower mounting or other antennas, and a panel antenna would, theoretically, provide more uniform coverage.

The question was whether a suitable UHF panel antenna could be found, one

Fortunately, Micro Communications Inc. (MCI) had just introduced exactly what we were looking for, a panel antenna known as the All-Band antenna, which is designed to operate over channels 14 through 69.

The antenna for Pelican Rapids was designed as a four-sided array of six vertically stacked bays, with integral radomes, mounted on a custom fabricated square tower section. At our request, the tower company manufactured the custom section first and then shipped it to MCI, where the antenna panels were mounted

and the phasing harness was assembled and tested.

Shipped whole

The completed antenna/tower section was then shipped directly to Pelican Rapids.

MCI also supplied the five-station combiner for the Pelican Rapids installation.

The combiner incorporates state-of-the-art interdigital filters for each channel, plus a patch panel, to allow any of the five transmitters to be tested into a dummy load without disturbing the on-air operation of the other four.

USER REPORT

Under FCC rules, LPTV stations are limited to a maximum of 1,000 watts of transmitter output power. Unlike other services, feedline losses cannot be offset with increased transmitter power, therefore minimizing line loss was extremely important to maximize the actual radiated power for each channel.

With this in mind, we field cut and installed rigid 1 5/8" flanged air dielectric line for all transmitter RF feeds. The feedline to the panel was 3 1/8" pressurized air dielectric heliax. Considering the feedline and combiner losses as well as the antenna gain, the site delivers an ERP ranging from 19.4 kW to 24.4 kW per station, depending on the channel.

Solid state system

Five identical UHF transmitters, each with code identifiers and remote control interfaces, were installed. The entire installation was solid state except for the single tube final amplifier. (At the time, fully solid state UHF transmitters at the 1 kW power level were unavailable, although, should more channels be added to the system in the future, solid state transmitters with final amplifiers would probably be the choice.)

VSWR performance of the system has been excellent, with virtually unmeasurable reflected power indicated on any of the transmitter power output meters.

The Rural Services site provides five channels of "premium" satellite-delivered television to the Pelican Rapids area on a subscription basis. Each channel also has a separate character generator for lo-

cal message insertion. Data may be entered on any character generator either at the site or via telephone or modem.

Remote operation

A full remote control system provides 32 channels of data monitoring and control to the five transmitters, as well as remote switching of video sources.
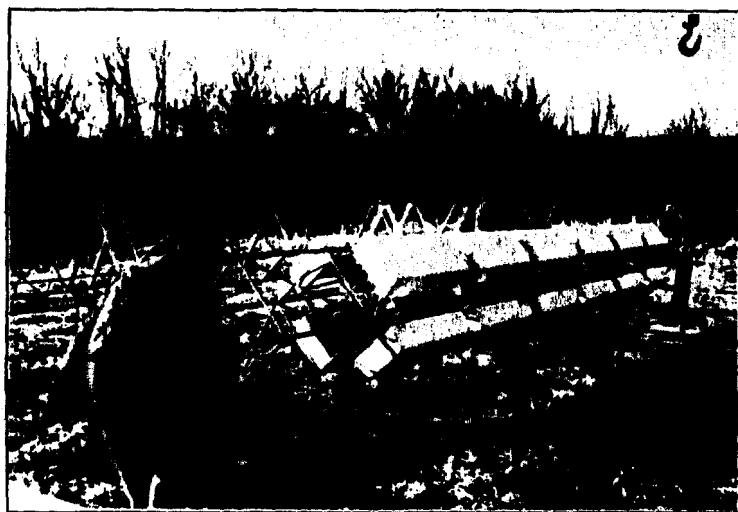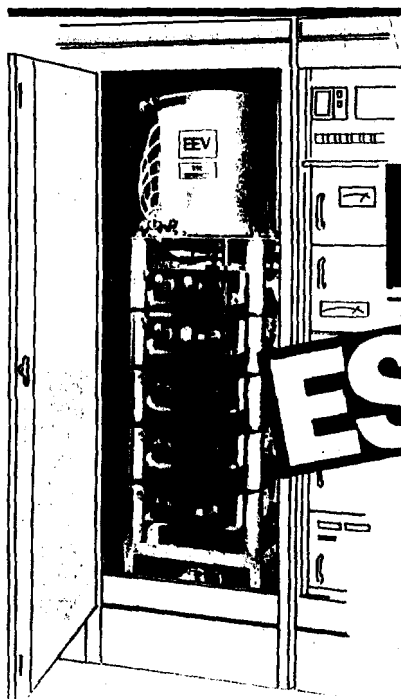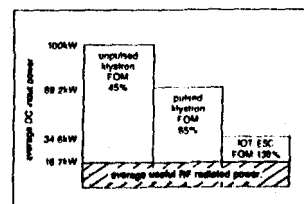
Although the system was not without some start-up problems, the facility has been operating for nearly a year with no perceptible change in the performance of the combiner or the antenna. Because the panel antenna is designed with integral radomes, antenna icing—even in the Minnesota snow country—has not been a problem.

Use of a panel antenna for the UHF LPTV facility would eliminate the problem of pattern irregularities due to tower mounting or other antennas ...

LPTV is a new service that has grown out of TV translator and booster technology and the need for television service in small markets where cable service is impractical. The Pelican Rapids installation demonstrates the viability of co-locating a number of LPTV transmitters, translators and/or boosters in a cost effective, elegant single-antenna installation.

Editor's note: George H. Werl Jr. left a career in radio in 1986 to become a broadcast consultant.

The opinions expressed above are the author's alone. For further information on the All-Band antenna, contact Dennis Heymans at Micro Communications: 603-624-4351, or circle Reader Service 110.

LOCATION AND COSTS
OF HDTV - ANTENNA SYSTEM

Many broadcasters came away from the 1992 NAB Conference with a better understanding of HDTV. Broadcasters also became aware of how fast the conversion to Digital was proceeding, and that <u>NOW</u> is the time to start planning for the new service.

QUESTIONS:

- Will HDTV require a new transmitting plant?

- What will be the requirements of an HDTV transmitter?

- Can the new HDTV equipment be co-located with the present facilities?

- Can the equipment be installed in a reasonable time-frame without interuption to the NTSC-ANALOG service?

- What are the cost factors?

- Can the antenna be mounted on the existing tower?

ASSUMPTIONS:

- All Full-Service NTSC stations will be allocated a new HDTV channel in 1993/1994.

- The new HDTV channel will be in the UHF band.

- The stations will have three years to apply for the assigned HDTV channels and will be required to construct the facilities upon grant of a construction permit.

- The present NTSC-ANALOG and new HDTV-DIGITAL signals will co-exist for 15 to 20 years.

- After that period, the NTSC-ANALOG plant will go black.

FUNDAMENTALS:

- The HDTV-DIGITAL signal and the NTSC-ANALOG signal must serve the same viewing audience.

- The NTSC-ANALOG signal will be the major revenue producer for the next 15 to 20 years.

CONCLUSIONS:

- The NTSC-ANALOG antenna will remain on top of the tower.

- The HDTV-DIGITAL antenna will be a Wrap-Around Antenna, mounted lower on the tower.

OTHER FACTORS:

- Recent studies have shown that in most cases, broadcasters will not be able to use a new tower for their HDTV-DIGITAL signal and will have to use their present tower.

- The new line and antenna will have to be integrated into the existing system without overloading the tower.

- Broadcasters will want to secure their new HDTV license by going on the air with a signal, even if it is initially less than the maximum power authorized.

NUMBER OF STATIONS:

The number of stations operating today (1992) are as follows:

	VHF	UHF	TOTAL
SYSTEMS ON AIR			
FULL SERVICE	617	691	1308
LPTV	438	772	1210
NEW HDTV STATIONS			
HDTV	-	1308	1308
	1,055	2,771	3,826

The LPTV stations are considered a secondary service, that is, the full service stations have priority over any conflicts or interference.

With the new HDTV-DIGITAL stations, there will be a total of 3826 operating TV stations. There is expected to be interference. The DIGITAL signal can increase the noise level of the ANALOG signal.

The FCC will issue channel assignments as soon as the proponent testing is complete (ref.1). If some of the UHF taboos are removed and a 100 mile co-channel spacing is permitted, assignments can be made for at least 98% of all stations.

STATIONS PER MARKET:

It is expected that the stations in the top 10 markets will be the first to add the new HDTV-DIGITAL service.

Markets	LoV	HiV	UHF	TOTAL
1 - 10	17	23	84	124
11 - 50	73	86	205	364
51 - 100	69	95	204	368
101-209	102	152	198	452
Total	261	356	691	1308

FORECAST:

The number of stations going on the air over the next 20 years is expected to follow the same curve as the projected number of receivers purchased.

	NEW RECEIVERS	NEW STATIONS
1st YEAR	0.5 MILLION	20
5th YEAR	2.0 MILLION	250
10th YEAR	20.0 MILLION	800
15th YEAR	60.0 MILLION	1300

TOWER CONSIDERATIONS:

Before considering the requirements of the new HDTV-DIGITAL transmitting facilities, some consideration has to be given to the location of the new plant.

The spacing studies by the FCC assume that the new station will be co-located with the existing station. Co-location assumes zero to two miles.

The FAA and local building permit problems associated with buying land and constructing a new tower will take five years to resolve. Therefore, a new tower is unlikely.

If a new tower cannot be located in the same area or antenna farm, there is a question as to whether the new pattern or "foot-print" is servicing the same viewing audience.

The evaluation criteria of signal quality is very different for HDTV-DIGITAL than it is for NTSC-ANALOG.

SHARED TOWERS:

A recent survey conducted of 1000 TV stations showed that 95% of all stations want their new antenna to be located on their present tower. This survey also tabulated the number of stations currently sharing the same tower. Stations now sharing a common tower preferred to share the same HDTV antenna. Therefore, the HDTV antenna should be broadband and be capable of handling all channels, regardless of the assignment (ref.4).

Number Sharing	Number of Towers
Two Channels	41
Three Channels	8
Four Channels	2
Five Channels	1
Six Channels	1
Seven Channels	1

Most of the present towers are stress limited, that is, the wind and ice load stress developed in the tower, due to "all" of the antennas and transmission lines, is at or close to the maximum limit. Furthermore, 50% of all towers are over 20 years old and were designed to satisfy the older wind load criteria. Any modification to the tower will require compliance with the new RS-222 wind load criteria.

INTEGRATED APPROACH:

Since the station must use an already stress limited tower, the problem is:

- Can the tower be modified without interfering with the NTSC-ANALOG signal?

- What type of antenna and line can be used?

- Can one "All Band" antenna be used for multi-channel installations?

- What are the tower modification costs?

- Are their trade offs of signal performance unique to HDTV-DIGITAL?

- What is the new coverage area?

- How does one compare coverage with quality of viewed signal for both services?

- What is the transmitter size and antenna gain?

It is clear that with so many trade-offs, an integrated design optimizing the parameter for both performance and cost is required.

SYSTEM:

The NTSC-ANALOG consists of an Exciter, Up Converter and Power Amplifier, a Transmission Line and Antenna and in some cases a Diplexer.
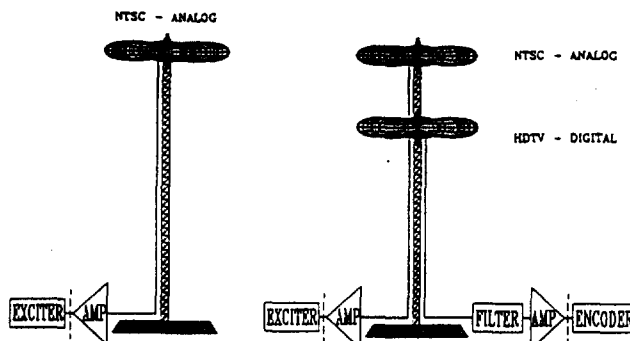
the HDTV-DIGITAL system, the Exciter will be replaced by an Encoder. Otherwise, the component requirement is the same, except for the addition of a Band Pass Filter (ref.2).

The Up Converter and Power Amplifier requirements are well within present day state-of-the-art technology.

The major difference between the two systems is:

NTSC-ANALOG quality is a function of signal level; the stronger the signal - the better the quality.

The HDTV-DIGITAL signal quality, like all digital transmission, is not a function of signal level. When the signal is too low, it will disappear, hence, the so called cliff effect.

Comparable signal levels based on 50/50 propagation curves are (ref.2):

NTSC-ANALOG   74 dbu - Grade A

HDTV-DIGITAL   53 dbu - Equivalent
                                  Grade A

The difference is based in part on improved receiver performance, high gain receiver antennas and lower loss transmission line compared to what was used in 1952 when the original NTSC contour curves were developed (ref.2).

ERP:

The ERP authorized by the FCC is expected to be between 250 and 500kW (ref.2).

A study of ERP, HAG and HAAT of all stations in the United States is presented in Pie Chart form as a function of incremental heights and kW (ref.2).

The results show that for present NTSC-ANALOG, 50% of all UHF stations are radiating less than 1,500kW (maximum allowed 5,000kW). Assuming the reasons for selecting the lower ERP will still apply, the average ERP for HDTV will be 100kW.

Type of Antennas:

The type of antenna will be a Wrap-Around (ref.4) since it will have to be mounted lower down on the tower. The wind load and ripple content of this antenna is a function of number of elements per bay and the relative location on the tower.

This type of antenna has three to six panels per bay, and are individually fed with a branch type of harness system, resulting in very broad band multi-channel performance.

An important advantage of this antenna is that because it is a multi-point source antenna, the radiation pattern can be tailored to the geographical area and/or viewing public.

To reduce the wind load on the tower, a small line with high antenna gain, rather than a low antenna gain and large transmission line, will be required. The small diameter line at UHF will restrict the transmit power.

TRANSMISSION LINE:

The transmission line will be semi-rigid coax. Waveguide has too high a wind area and is dispersive, that is, it has a significant group delay over the 6 MHz band. The stress developed in the tower legs is more dependent on the wind load of the transmission line than the antenna. In some installations, the stress developed due to the transmission line is five times that due to the antenna (ref.3). In most installations, the maximum line size permitted will be 3 1/8".

FILTER:

To reduce interference, a Band Pass Filter with out of band attenuation of 50db will be required (ref.2). These are similar to the direct coupled and high power interdigital filters that MCI has been using on channel combiners.

PRICING ANALYSIS:

The cost analysis was based on three different antenna/line combinations mounted on two locations of a 1000 ft tower. It was assumed the tower was already at the 100% stress level.

The additional wind load was calculated. A new stress analysis was developed. The cost of new guys and additional steel required to bring the tower up to the RS-222D level was determined.

TRANSMIT POWER ANTENNA GAIN:

The new stress levels were calculated for three different options, all with an ERP of 250kW.

	1	2	3
ERP	250kW	250kW	250kW
Antenna Gain	5.5	18	32
Power into Ant.	45kW	14kW	7.8kW
Line Size	6 1/8	3 1/8	3 1/8
Efficency	75%	47%	75%
Length (Ft)	1,000	1,000	500
Tx Power	60kW	30kW	10kW
Tower Height (Ft)	1,000	1,000	500

STATION COSTS:

The overall costs for the three options shown above are listed below.

	1	2	3
Tx Costs	$600,000	$350,000	$150,000
RF Comps	200,000	100,000	65,000
Tx Line	150,000	45,000	25,000
Antenna	50,000	140,000	180,000
Tower Analysis	15,000	15,000	15,000
Tower Modification	100,000	80,000	70,000
TOTALS:	$1,215,000	$730,000	$550,000

These figures show the cost of tower modification as well as the stress analysis.

REFERENCES:

(1) FCC Channel Allotments for Maximum Coverage
by R. P. Eckert - FCC
1992 NAB HDTV World Conference Proceedings

(2) Antenna & Transmission Line for
the Simulcast Period
by T.J. Vaughan and J. Banker - MCI
1992 NAB HDTV World Conference Proceedings

(3) Tall Towers for Super Power TV
by T.J. Vaughan - MCI and J. Windle - Stainless
1989 NAB Conference Proceedings

(4) MCI has been supplying All Band
antennas with power handling capabilities
up to 240kW to the International Market
for a number of years.

(5) N. Smith - Consultant
presented at the NAB ENG Conference 1971

(6) This paper was presented in part at the 1992
HDTV-World Conference

ANTENNA
AND
TRANSMISSION LINE
FOR THE
SIMULCAST PERIOD

by Thomas J. Vaughan & James Banker
Micro Communications, Inc.
Manchester, New Hampshire

Report #6116

Presented at the
1992
HDTV World Conference
Las Vegas, Nevada

ANTENNA AND TRANSMISSION LINE
FOR THE SIMULCAST PERIOD RECEIVED

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Manchester, New Hampshire

JUL 1 6 1992

FCC MAIL BRANCH

SUMMARY

In 1993, the FCC will be issuing new licenses for High Definition Television (HDTV) or the new Advanced Television (ATV) for use during the Simulcast Period.

It is assumed that the new ATV signal will be digital.

This paper considers the effect the RF system will have on the digital signal. Pass band tilt and group delay are new parameters that must be considered.

Broadcasters should investigate their own tower as a location for the new ATV line and antenna. In some installations, it will be possible to diplex the ATV signal and the NTSC signal into one antenna.

Many stations will be able to use wrap around antennas lower down on the tower and meet or exceed the quality level of the NTSC signal.

Predicted performance data for filters, transmission line and antennas is included in this paper.

The practicality of wrap around antennas is based on a study of ERP, HAAT and HAG of all operating TV stations in the United States. This study is included as an appendix.

BACKGROUND

The present plan proposed by the FCC is to allow a three year period for each station to apply for a license and an additional two years for construction.

Stations will transmit the NTSC program and the ATV program for a period of 10 to 15 years, or until all of the NTSC receivers are replaced with ATV receivers.

This is called the Simulcast period.

How many stations will apply and how many will go on the air depend on many things.

A. Are the Broadcasters convinced there is a market for this new service?

B. Can broadcasters get permission to construct new facilities with all the restraints on building? (e.g. FCC, FAA, Local Zoning, etc.)

C. Can broadcasters afford to construct the new facilities?

Since this will be a full service station, advance planning should now be underway for building, land and tower.

Allocation studies assume the new tower will be co-located. This is being interpreted as being on the same tower or within a 1 to 2 mile radius of the existing tower.

The time required to find and implement a new site could take three to five years.

The major tasks are listed below:

A. Real Estate siting and buying
   - estimated 2 months

B. FAA approval required to insure
   against aircraft interference
   - estimated 6 months

C. FCC final approval assuming there
   is no bartering or competition
   for channel assignment
   - estimated 6 months

D. Local zoning approval
   - the concerns with respect to
   real estate value, non-ionized
   radiation and interference with
   other services is very time
   consuming, many times resulting
   in litigation.
   - estimated 12-24 months

E. Equipment purchase and delivery
   - estimated 12 months

The conclusion is the broadcaster
should try to use his present
facility. Although many towers are
wind load limited, it will be
possible in many cases to re-enforce
the tower.

The new UHF ATV transmitter power
will be 30kW or less.

The options for the transmission
line and antenna are either:

A. Install a new line and antenna on
   the existing tower

B. Diplex the ATV signal into the
   present line and antenna

Although diplexers are currently
available, the transmission line
would have to be replaced because it
is now power limited and frequency
sensitive. Likewise, the antenna
would have to be replaced with a new
"All Band" antenna.

The most likely scenario would be a
new line and antenna.

Studies being done by the Office of
Engineering Technology of the
Federal Communications Commission
(OET-FCC) conclude that 98% of the
operating stations can be given a
new channel.

These studies are based on mileage
separation, interference and
eliminating of some Taboos.

Some VHF stations will be assigned
new VHF channels, but most VHF and
all UHF channels will be assigned
UHF channels.

If the new ATV channel is to have
the same radiating pattern (Foot
Print), the antenna should be on the
same tower.

SPECIFICATIONS

The ATV transmitter will not require
high level diplexing. The basic
system will include:
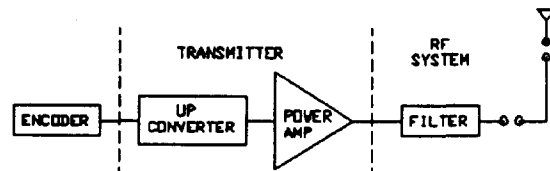
Typical ATV Transmitter System
specifications will be:

Frequency Response:	± 1dB
Group Delay	±50 nsec.
Differential Gain	3%
Differential Phase	3 degrees
ICPM	2 degrees
HVM	50dB
Transient Response	1.5%

The RF system includes filters,
transmission line and antennas.
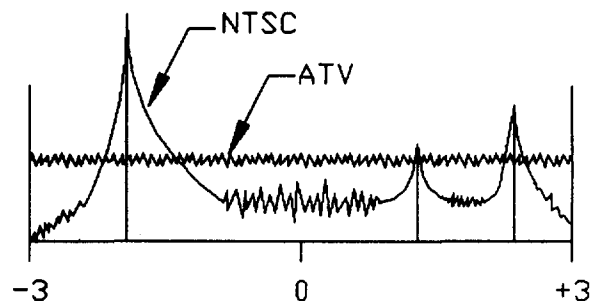
The specification for the RF system
will be:

Frequency Response	±1.0dB
Group Delay	±30 nsec
non correctable	
Return Loss	-20dB
Out of Band Response	-50dB

The important system specification is frequency response or flatness of response, group delay and reflection.

Group delay in the RF system for an NTSC signal is normally not measured or calculated but is important for a digital ATV signal.

The RF portion of the system is passive, essentially loss-less and reciprocal, therefore, pass band tilt and group delay, can be analyzed using traveling wave matrix.

Any two reflections will interact and effect pass band tilt and group delay.

The transmission loss and group delay for different reflections (VSWR = 1.2, 2.0, 5.0) spaced one foot and 12 feet apart, are shown in figure 1.

For impedance and voltage gradient reasons, reflections are kept very low and for bandwidth optimization, matching circuits are always close to the source of reflections.
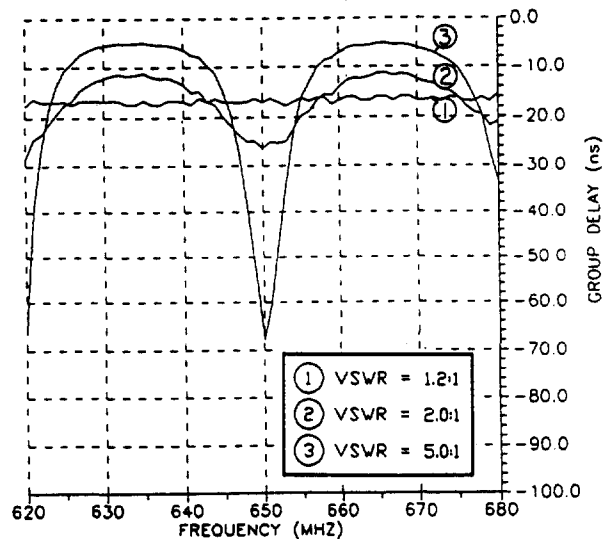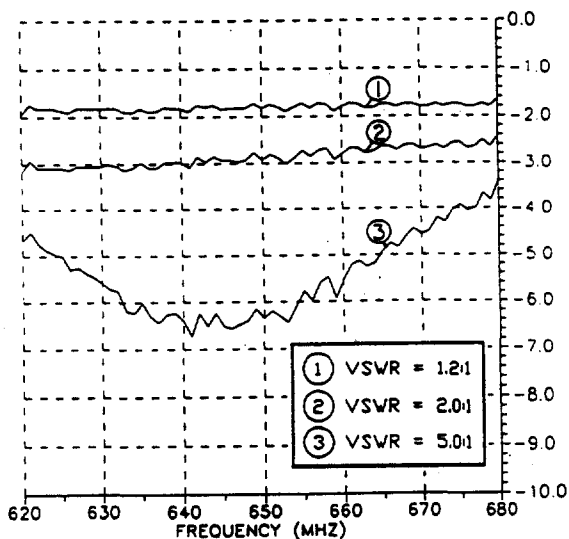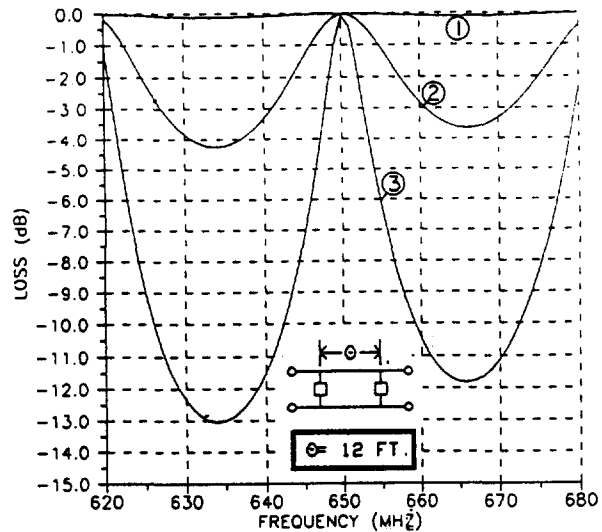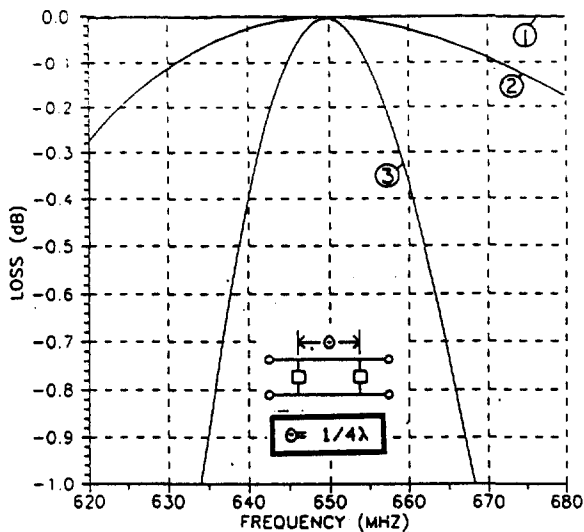
Fig. 1: Transmission Loss and Group Delay

FILTERS

The Allocation Plan and Bit Error Rate (BER) of the digital signal is a function of the out of band response.

Bandpass filters will therefore be required.

The transmission loss and group delay of waveguide bandpass filters with 4, 6, 8 and 10 sections is shown in figure 2 for a Tchebyscheff ripple of 0.5dB and 0.1dB.

HIGH POWER FILTER-TCHEBYSCHEFF TYPE
CHANNEL 40   RIPPLE = 0.5 dB
4,6,8,10 SECTION
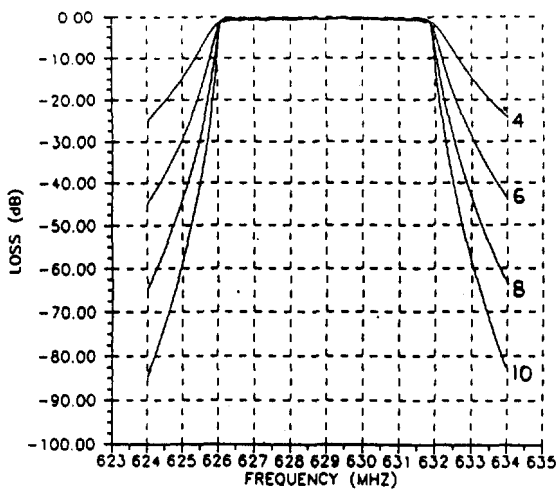
HIGH POWER FILTER-TCHEBYSCHEFF TYPE
CHANNEL 40   RIPPLE = 0.1 dB
4,6,8,10 SECTION
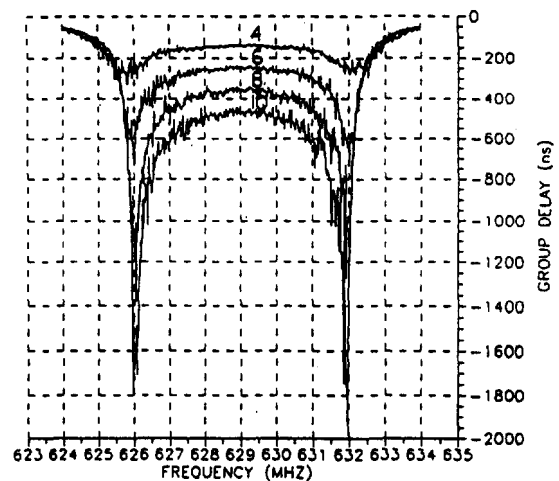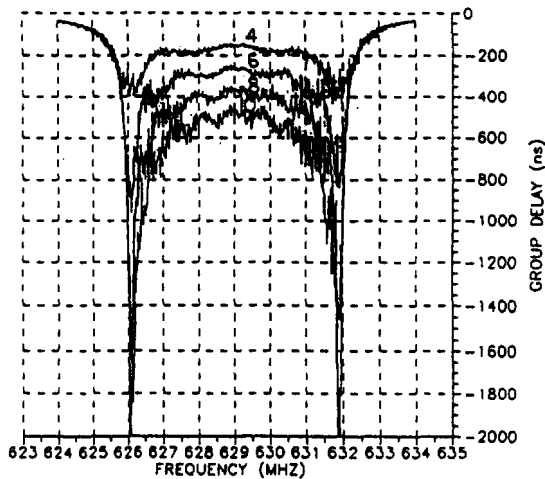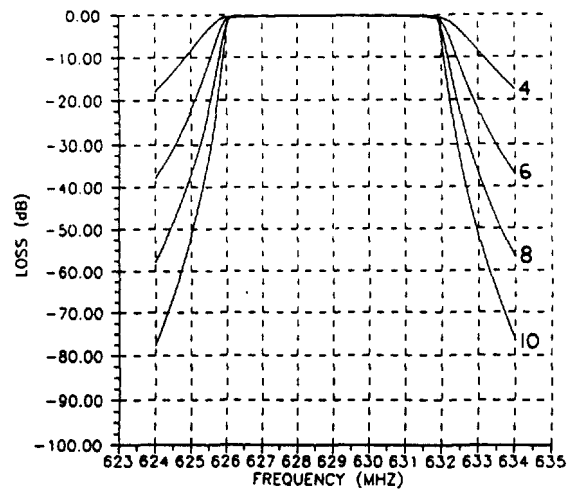
Fig. 2: Transmission Loss and Group Delay
of Waveguide Bandpass Filters

TRANSMISSION LINE

The ERP for the NTSC system is defined by Peak Sync Power. The ERP for the ATV is defined by Average Power, which could be 15-18dB below NTSC Peak Sync Power.

	NTSC	ATV
Peak/Peak Sync	0.0dB	-6dB
Black Picture	-2.2dB	-
Average Picture	-4.2dB	-15dB

The ERP and likely transmission line size will be:

	NTSC	ATV
UHF ERP kW	5,000	250/250
Antenna Gain	45	11/18
Power Into Antenna kW	108	23/15
Line	W/G	Coax/Coax
Size (in.)	15"	6 1/8 / 3 1/8
Efficiency (L=1000 Ft)	90%	75% / 50%
Tx Power kW	120	30/30

ANTENNAS

A. Antenna Analysis

The emphasis of flatness on response and group delay over the six MHz Band has required us to reevaluate the method of calculating antenna gain.

The gain of an antenna is defined as the ratio of maximum intensity in a given direction to the maximum intensity in the same direction from a reference antenna with the same input power.

$$D = \frac{E_{max}^2}{\left(\frac{1}{4\pi}\right) \iint E^2(0,\phi)\, d\Omega}$$

Where $d\Omega$ is a unit of solid angle which requires integration in all space. It is common practice to evaluate the gain in two cardinal planes.

$$G= [\text{AZIMUTH GAIN}] \times [\text{ELEVATION GAIN}]$$

$$D = \frac{4\pi E_{max}^2}{\int_0^{2\pi} \int_0^{\pi} E^2(0,\phi)\, \sin 0\, d0\, d\phi}$$

The azimuth pattern is calculated and the RMS value determined.

The elevation pattern is calculated assuming the azimuth pattern is omni directional. The resultant gain is the product of the azimuth and elevation gain.

For angles other than the cardinal plane, the gain or ERP is assumed to be the signal at the peak reduced by relative field (in dB) as measured in the cardinal plane to the point of interest.

This assumption can result in significant errors.

To determine flatness of response, a new method of analysis had to be developed that performs the numerical integration in three dimensions; over the entire array.

This integration samples 26,000 points in space.

It is especially useful when evaluating signals near side lobes or when the beam tilt is not the same in all directions.

This new technique also permits the calculation of Relative Field, ERP and Field Intensity individually and at each point in space.

Of concern, here is the variation in gain over the six MHz band at a location such as near nulls where the array or element pattern would be expected to vary.

An example of a 10 element branching feed array is shown in figure 3A (Relative Field), 3B (ERP) and 3C (Signal Strength).
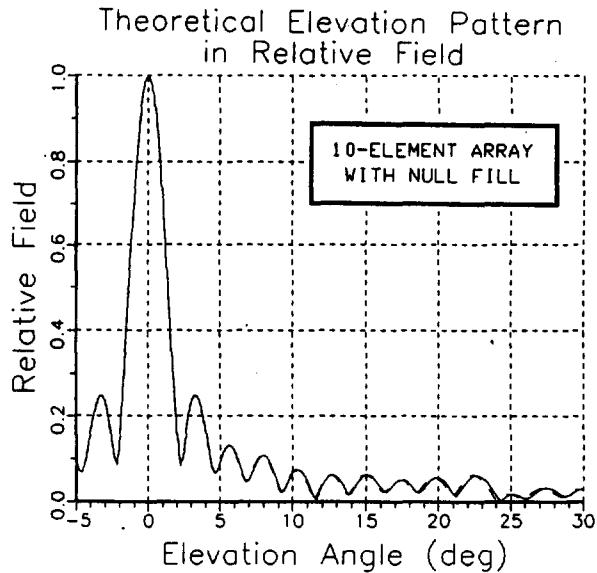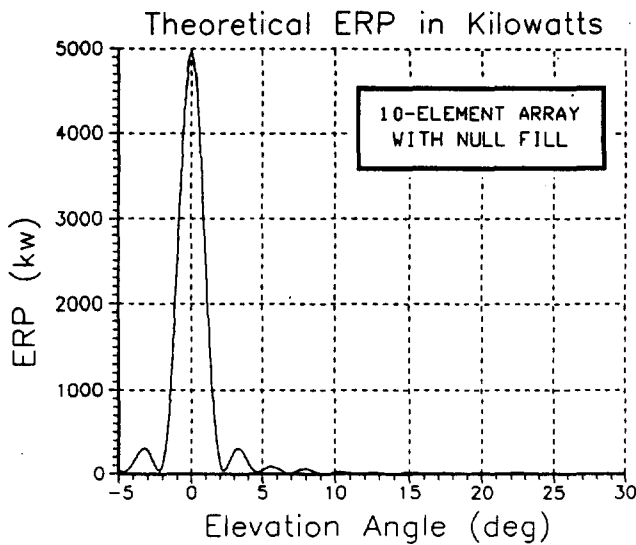
Theoretical Elevation Pattern in Relative Field

10-ELEMENT ARRAY WITH NULL FILL

Fig. 3A: Relative Field

Theoretical ERP in Kilowatts

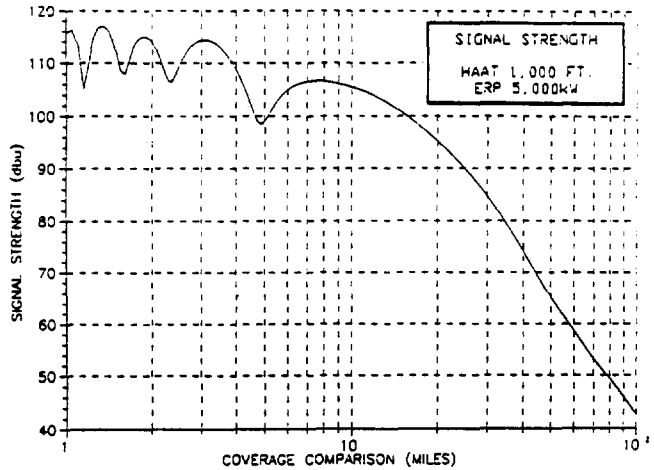10-ELEMENT ARRAY WITH NULL FILL

Fig. 3B: ERP

SIGNAL STRENGTH
HAAT 1,000 FT.
ERP 5,000kW

Fig. 3C: Signal Strength

The variation in signal strength from 1 to 10 miles over a 6MHz band is shown in table 1. The pass band tilt is less than 0.01dB in the main beam and less than 0.7dB in the vicinity of the nulls.

NEAR-IN SIGNAL STRENGTH

HAAT = 1000 FEET
ERP = 5000 kW

Distance (miles)	Signal Strength (dbu) (650MHz)	(656MHz)	(Difference)
1.00	115.65	114.95	0.70
1.25	114.65	113.91	0.74
1.50	111.53	112.32	-0.79
1.75	113.75	113.27	0.48
2.00	113.90	114.07	-0.17
2.25	107.56	108.03	-0.47
2.50	109.31	108.70	0.61
2.75	113.06	112.72	0.34
3.00	114.23	114.08	0.15
3.25	114.00	113.97	0.03
3.50	112.86	112.93	-0.07
3.75	111.02	111.19	-0.17
4.00	108.56	108.83	-0.27
4.25	105.48	105.87	-0.39
4.50	101.88	102.34	-0.46
4.75	98.93	99.13	-0.20
5.00	99.04	98.65	0.39
5.25	100.95	100.43	0.52
5.50	102.72	102.26	0.46
5.75	104.02	103.64	0.38
6.00	104.95	104.63	0.32
6.25	105.59	105.32	0.27
6.50	106.03	105.80	0.23
6.75	106.33	106.12	0.21
7.00	106.51	106.32	0.19
7.25	106.60	106.44	0.16
7.50	106.64	106.49	0.15
7.75	106.62	106.48	0.14
8.00	106.56	106.44	0.12
8.25	106.48	106.36	0.12
8.50	106.37	106.26	0.11
8.75	106.24	106.14	0.10
9.00	106.10	106.01	0.09
9.25	105.96	105.87	0.09
9.50	105.80	105.72	0.08
9.75	105.64	105.57	0.07
10.00	105.49	105.41	0.08

All of the antennas discussed use the center fed branching feed system.
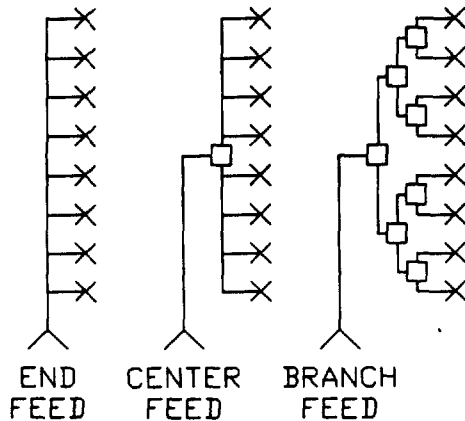
With these center fed systems, there is no beam steering on tilt. Since the path length to each radiator is electrically the same for any frequency.

Group delay is the non-linear phase or the derivative of phase with frequency.

The space vector of any multi-source array will vary with azimuth position.

The variation will depend on the spacing between the radiators, the element pattern and the phase center diameter of the radiators.

The variation over a 6MHz band for center fed array using a branching feed will be:

$$\Delta \phi = \frac{\Delta f}{f} \times \frac{2\pi}{\lambda} \times \frac{D}{2}$$

where D is the phase center diameter of the radiators. The phase variation for different phase center diameters is linear and tabulated below.

Phase Center Diameter (Ft.)	(λ)	Phase (Degrees)	Group Delay
2	1.4	2.3	<1 nsec.
4	2.7	4.7	<1 nsec.
7	5.2	8.6	<1 nsec.

B. Antenna Quality

The NTSC signal is analog. The quality of analog signals is a function of signal strength.

Grade	Signal
Excellent	78 dBu
Fine	69 dBu
Passable	64 dBu
Marginal	60 dBu
Inferior	52 dBu

The digital ATV signal above a certain level is independent of signal strength.

The service contours were developed based on the following criteria.

		NTSC "A"	NTSC "B"	ATV
(A)	Receiver			
	Thermal Noise	7	7	8
	Receiver Noise	15	15	10
	Carrier/Noise	30	30	15
		52	52	33
(B)	Antenna			
	Antenna Factor	16	16	16
	Line Loss	5	5	4
	Antenna Gain	-8	-13	-10
		13	8	10
(C)	Time/Location			
	T 90%	3	4	10
	L 70%	6	0	0
		9	4	10
(D)	Total	74 dBu	64 dBu	53 dBu

The ATV signal level greater than 53 dBu should result in a grade level of Excellent.

The predicted signal level using the FCC/CCIR criteria for an antenna at 1,000 Ft. and 500 Ft. with ERP's of 5000kW, 500kW and 100kW is shown in figure 4.
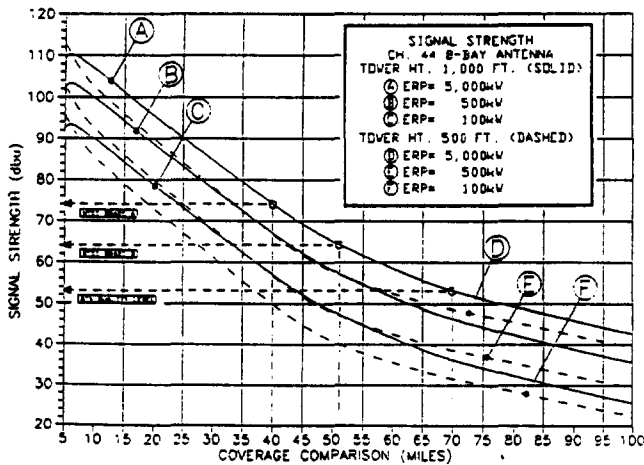

Fig. 4: Predicted Signal Level

This curve shows that for a full service NTSC signal, the Grade A and B will be 40 and 50 miles respectively.

AN ATV signal at 40 miles would require an ERP of 100kW at 1,000 Ft. and an ERP of 250kW at 500 Ft.

The point here is if the existing FCC/CCIR curves are to be used to predict signal levels, the simulcast antenna for equal or better performance can be located lower on the tower.

C. Types of Antennas
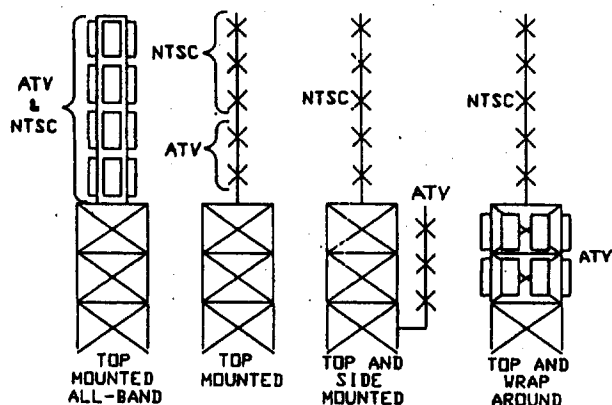
An antenna can be either top mounted or side mounted.

It is assumed that the station considering adding ATV service will either:

(A) Replace their top mounted antenna with an All Band antenna.

This would be the most efficient from a cost point of view..

The two channels can be diplexed into the same transmission line and antenna.

Broadband transmission lines and waveguide is now available that will handle two channels spaced up to 120MHz.

"All Band" antennas are available that will cover each band (5 LoV channels or 7 HiV channels or 55 UHF channels). No antennas are available to accommodate both the VHF and UHF channels simultaneously.

(B) Replace the top mounted antenna with a stacked NTSC and ATV antenna.

(C) Leave the NTSC top mounted antenna and add a side mounted antenna.

With this approach, the ATV pattern will be distorted. The ripple in the azimuth pattern can be as high as ±6dB.

(D) Leave the NTSC top mounted antenna and add a wrap around antenna.

The wrap around antenna can produce any pattern from a perfect Omni to a Directional Pattern.

One of the main disadvantages with the above three solutions is the need for a second transmission line.

D. Tower Size

Before considering the performance of top mounted or wrap around designs, it is necessary to have some information on the tower leg spacing.

A study was made on all full service stations; both commercial and non-commercial.

Number of Stations

Low VHF	261
High VHF	356
UHF	691
	1308

The number of stations sharing the same tower is shown below:

Sharing	Number of Towers
Two Channels	41
Three Channels	8
Four Channels	2
Five Channels	1
Six Channels	1
Seven Channels	1

This data (see Appendix A) shows that 34% of all towers are between 900-1200 Ft. and that 29% of all towers are less than 500 Ft.

The numbers of towers by market and band is listed below:

Markets	LoV	HiV	UHF
1- 10	17	23	84
11- 50	73	86	205
51-100	69	95	204
101-209	102	152	198
	261	356	691

This data shows that in the top 10 markets, 22% of the towers are less than 300 Ft. and 24% of the towers are between 900 and 1200 Ft. In the next 50 markets, 38% are between 900 and 1200 Ft. with equal distribution. In the bottom 100 markets, the largest grouping is less than 200 Ft.

The tower size as a function of height is listed below:

Tower Height	Leg Spacing
0 - 600 Ft.	4 Ft.
600 - 900 Ft.	4/5 Ft.
900 - 1200 Ft.	7 Ft.
1200 - 2000 Ft.	10 Ft.

The above data is eschewed somewhat by New York and Chicago, where the antennas are mounted on tall buildings. The tower heights of all stations on Mt. Wilson, Los Angeles and other mountain top locations are very low.

It is assumed that the conversion to ATV will occur in the major markets first.

E. Top Mounted Antennas

It is assumed that if a top mounted antenna is to be used, it will replace the existing top mounted antenna and therefore will have to be broadband and cover many channels.

MCI has designed many top mounted antennas with power levels up to 240kW with as many as 5 channels into one antenna.

The radiation pattern of channel 14, 44 and 69 for a 10 Bay array is shown in figure 5. Also shown is the predicted signal strength superimposed on the New York City area.

Specifications:

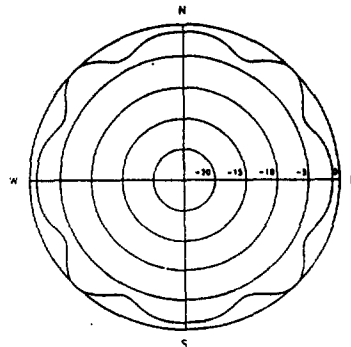|			
Antenna Size:	10-BAY x 4	Tower Face:	2.0 Ft
Length:	37.50 Ft	HAAT:	750 Ft
Wind Area:	134 Sq Ft	ERP:	2000 Kw (CH-44)
		Gain:	41 (CH-44)

Theoretical Azimuth Pattern in dB
UHF BAND IV/V   10-BAY X 4 OMNI
CHANNEL 14
24 INCH SQUARE TOWER
14-A
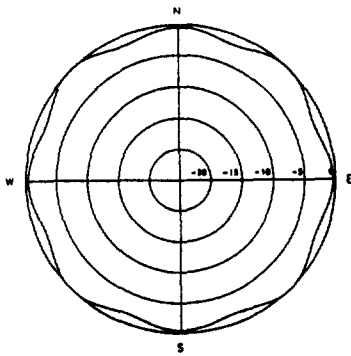
CH-14

Theoretical Azimuth Pattern in dB
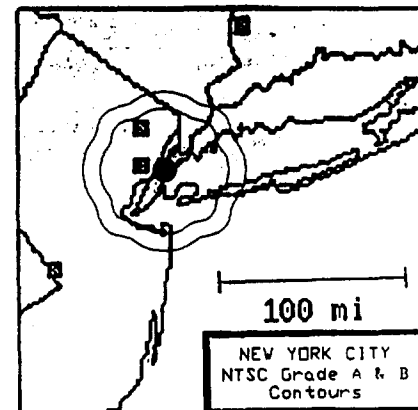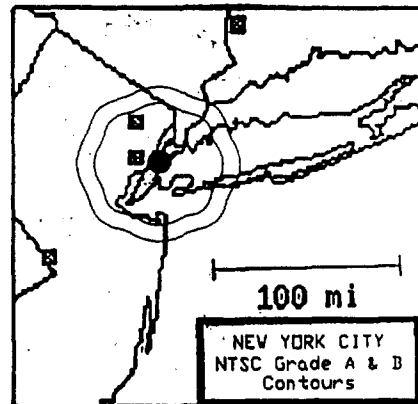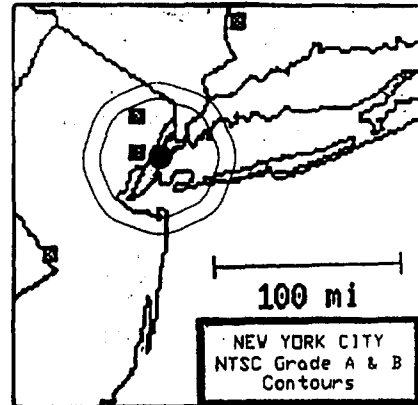UHF BAND IV/V   10-BAY X 4 OMNI
CHANNEL 44
24 INCH SQUARE TOWER
44-A
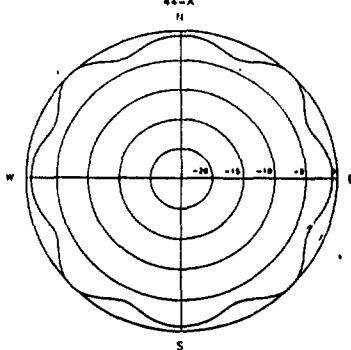
CH-44

Theoretical Azimuth Pattern in dB
UHF BAND IV/V   10-BAY X 4 OMNI
CHANNEL 69
24 INCH SQUARE TOWER
69-A

CH-69

100 mi

NEW YORK CITY
NTSC Grade A & B
Contours

100 mi

NEW YORK CITY
NTSC Grade A & B
Contours

100 mi

NEW YORK CITY
NTSC Grade A & B
Contours

Fig. 5: Radiation Pattern

Specifications:

Relative Azimuth Field

Antenna Size: 16-BAY x 12
Length: 60.0 Ft
Wind Area: 405 Sq Ft
Tower Face: 7.2 Ft
HAAT: 600 Ft
ERP: 6300 Kw (CH-28)
Gain: 58.5 (CH-28)
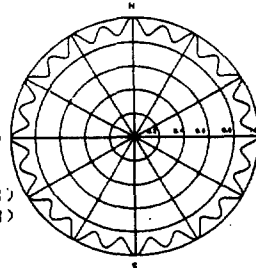
CH-28

Specifications:

THEORETICAL AZIMUTH PATTERN
IN RELATIVE FIELD
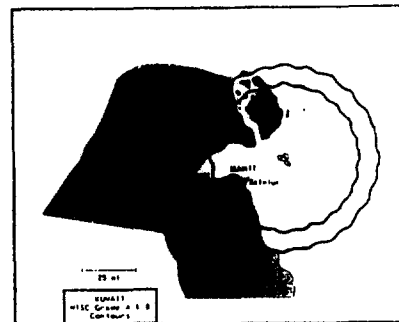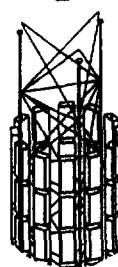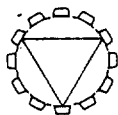
Antenna Size: 10-BAY x 3
Length: 103.7 Ft
Wind Area: 200 Sq Ft
Tower Face: 7.2 Ft
HAAT: 902 Ft
ERP: 1600 Kw (CH-10)
Gain: 40 (CH-10)
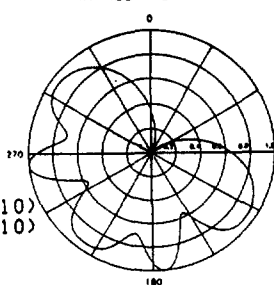
CH-10
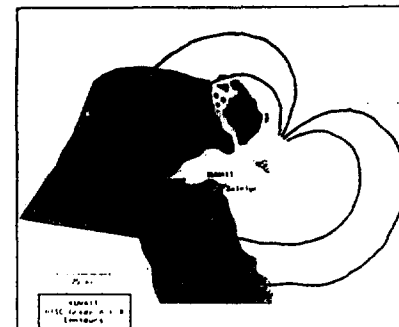
Fig. 6: 12 Element Wrap Around Antenna

F. Wrap Around Antenna

It is assumed that the first ATV stations will be located in top markets. Wrap arounds can either be complete or partial.

Complete wrap arounds will have a number of elements and element functions consistent with the tower size or phase center diameter.

An example of a 12 element wrap around, azimuth pattern in Relative Field and Grade A and B contours is shown in figure 6.

Partial wrap around antenna is when fewer than the optimum number of elements are used.

The tower study showed that most towers are 5, 7 and 10 Ft. leg to leg spacing.

Rather than use 9 or 12 elements per bay, we investigated the performance of using only three elements per bay.

The advantage of fewer elements is less wind load. The disadvantage is the increase ripple in the azimuth plane.

As shown in figure 4, the digital ATV signal out to the radio horizon can tolerate a large ripple factor before there would be any degradation in picture quality.

The ripple in the azimuth pattern for the 5, 7 and 10 Ft. tower with one panel per face is tabulated below.

Tower	5 Ft.	7 Ft.	10 Ft.
Ripple	±3dB	±4dB	±6dB
Phase Center Diameter	1.9	2.6	3.8

With the proper choice of element parameter, the band width need not be sacrificed.

The azimuth pattern and predicted signal strength is shown in figure 7 for 5 Ft., 7 Ft. and 10 Ft. towers for CH-44.
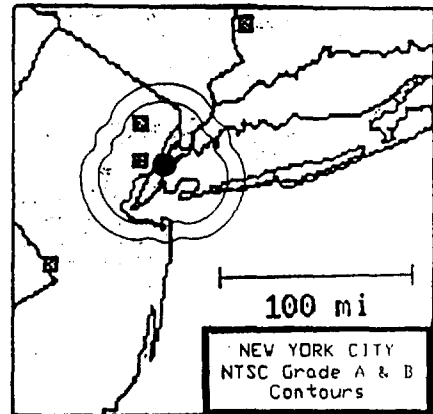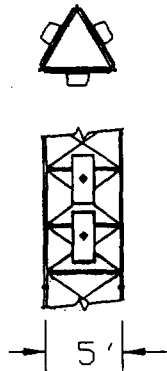
Specifications:

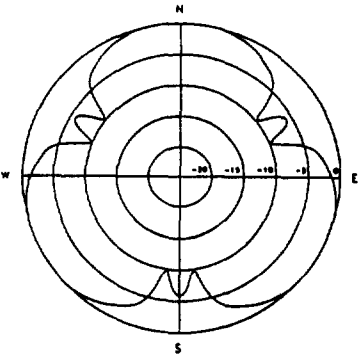|			
Antenna Size:	10-BAY × 3	Tower Face:	5, 7 & 10 Ft
Length:	37.50 Ft	HAAT:	750 Ft
Wind Area:	83 Sq Ft	ERP:	2900 Kw (CH-44)
		Gain:	48 (CH-44)

Theoretical Azimuth Pattern in dB
UHF BAND IV/V   10-BAY × 3 OMNI
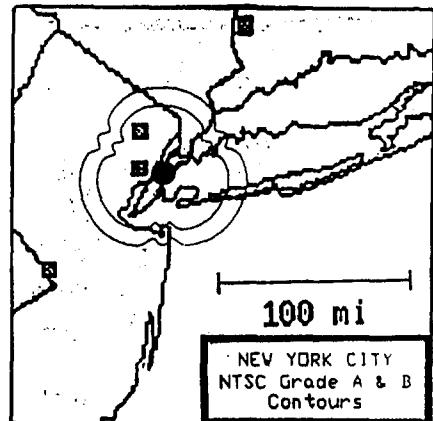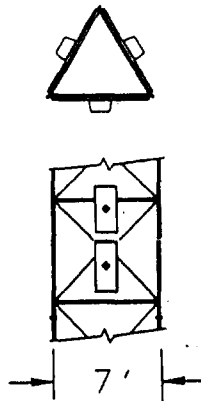CHANNEL 44
60 INCH TRIANGULAR TOWER
44-B

CH-44

5'

NEW YORK CITY
NTSC Grade A & B
Contours
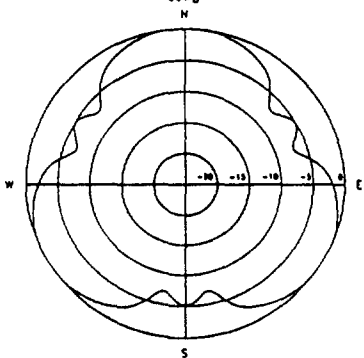
Theoretical Azimuth Pattern in dB
UHF BAND IV/V   10-BAY × 3 OMNI
CHANNEL 69
84 INCH TRIANGULAR TOWER
69-C

CH-44

7'

NEW YORK CITY
NTSC Grade A & B
Contours

Theoretical Azimuth Pattern in dB
UHF BAND IV/V   10-BAY × 3 OMNI
CHANNEL 44
120 INCH TRIANGULAR TOWER
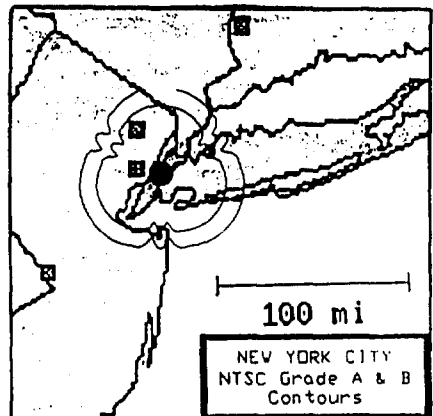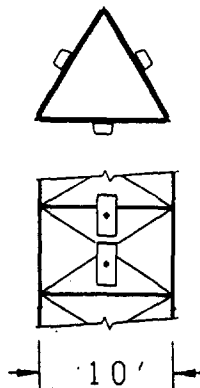44-D

CH-44

10'

NEW YORK CITY
NTSC Grade A & B
Contours

Fig. 7: Azimuth Pattern and Predicted Signal Strength